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Design and Evaluation of Tools to Support Command and Control Warfare Team Activities

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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

This report describes the design and evaluation of collaborative software tools that can be used to support navy command and control warfare (C^2W) team activities. It is organized into six sections. The first section provides a background to the issues involved in evaluating collaborative technologies.

The second section describes three general activities engaged in by military teams:

- *Team management activities* involve building a team, defining the process that the team will use to focus and coordinate its actions and then providing support and direction for the team as it operates.
- *Mission planning activities* involve use of the team to select the objectives to be pursued during a mission and then to generate and evaluate contingency plans for achieving those objectives.
- *Mission operations activities* involve the use of the team to perform some of the steps required to execute a mission plan.

The third section focuses on the activities of a C^2W team and describes the information that the team uses and shares during team management, mission planning, and mission operations. This information includes the role each team member will play, the procedures that must be followed to carry out each role, and the data that must be collected and shared to perform those roles.

The fourth section uses the prior description of C^2W team activities and information needs to suggest ways in which the team could be supported to improve its performance. Many of the C^2W team's activities involve information collection or information interpretation. Some of these information processing tasks are performed by individual team members, while others require collaboration. Support for collaboration can be provided for either the mechanics of collaboration (information transfer) or for its product (information interpretation). Since collaboration assumes that team members will recognize and share data, the first level of support entails improving individual performance in identifying and collecting mission-relevant data. The next level of support involves features that can be used to improve the efficiency with which information is shared. Once information has been collected and shared, support could also be provided for interpreting the shared information and/or responding to its content.

The fifth section investigates the features provided by several commercial off-the-shelf collaborative software support tools. Because team members may be collocated or distributed in either space (members in different locations) or time (different work shifts, time zones, or availability windows), tools with features that support these distributions are described. Limitations of the tools are noted, including estimates of some of their implementation costs and their ease of use.

The sixth section compares the features provided by the commercial off-the-shelf collaborative tools with those identified in the fourth section as desirable for supporting C^2W team activities. The commercial tools provide some of the message transmission features, management features, and information interpretation features needed to support team collaboration. Since they were developed for different purposes and for different end users than those encountered in C^2W, they provide only partial support for C^2W tasks. The utility of the tools in improving C^2W team performance will

depend on a balance between the support they provide and the resources (time, attention, memory) that the team must commit to their use.

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INTRODUCTION

Collaborative technologies are those technologies that facilitate the communication, exchange, and integration of information and ideas among a group of individuals working together to complete a shared task. Current organizational theory (Cascio, 1995) has highlighted a shift away from individual, task-based, independent work toward process-oriented work among a coordinated group, or team of people concentrating on accomplishing a joint set of goals by shared effort. A similar paradigm shift has been occurring in the military as well.

The mission of the NRaD Collaboration Laboratory (COLAB) is to allow the systematic empirical study of the utility of modern computer networking and software technologies for augmenting team performance in solving problems and completing tasks in the domain of command and control warfare (C^2W). Specific tasks in this laboratory enable collaborative technology demonstrations, evaluations, workflow analyses, and assessments of distributed team activities, such as collaborative problem solving, situation assessment, planning and decision making using collaborative technologies.

This report defines a process for choosing features in tools used to support team activities. It provides a framework for selecting tools with appropriate features and suggests a method for combining those features and evaluating the effectiveness of the resulting support.

BACKGROUND

The prevalence of desktop computers, as well as networking technology to connect them, has been cited as a leveraging technology to facilitate group collaboration. Together, the maturing of these technologies has led to a whole new class of software commonly referred to as "groupware". Central to this class of software is the premise that groupware will support collaborative efforts of teams. Team-based work organizations are developing at all levels of the military, including Joint Staffs, Fleet Staffs, and Battle Group Staffs for performing strategic and tactical planning as well as mission operations.

Recognizing the potential far-reaching importance of these trends to the Navy, NRaD established a test bed (COLAB) to evaluate such computer systems, composed of hardware, software, and networks, for use in joint and naval activities most likely to be affected by the emerging technologies, especially command and control. The test bed has been designed to assess collaborative technologies for command, control, communications, computer and intelligence (C^4I) teams during simulated planning and operational activities.

Agencies initially identified and contacted to receive the results of COLAB efforts were CINCLANTFLT and CINCPACFLT Headquarters where distributed networks of anchor desks are being established and where there is a need for information about the effectiveness of collaborative tools.

TEAM ACTIVITIES

Military team activities generally involve three mission-related functions. The first function involves tasks that support and coordinate the team's activities (management). The second involves tasks designed to define a problem, specify objectives, and select a course of action that will achieve those objectives (planning). The third involves execution of a planned course of action in pursuit of the mission's objectives (operations).

When a team is tasked to plan or pursue a course of action, it does so by delegating tasks to team members. Some of these tasks will be performed by individuals, while others will require interactions with other team members.

Once these tasks are well defined, the level of support required by the team members to perform the tasks can be determined so that tools to support them can be identified and evaluated. Support can be designed to either improve team performance by streamlining or improving the quality of its interactions, or to improve individual team member's task performance so that the individual products that they share will be of higher quality.

Since the C^2W team's duties are currently undergoing redefinition, it is difficult to identify all the features required in tools designed to support them. This difficulty is increased by the lack of a formal analysis of specific team functions and tasks in the current team instantiations. Although more information would allow tools to be selected for specific team needs, the functions performed by the C^2W team share characteristics that are common to military teams organized for many purposes. Some of these C^2W activities are outlined below so that tools can be evaluated according to their support for the team activities and the resources required to utilize that support.

TEAM MANAGEMENT

Management activities coordinate and support the operation of the team and the process it implements. Management activities involving team organization may begin prior to the planning and operational stages of a mission. Those activities involving leadership and monitoring of the team's performance take place throughout the mission and can either be distributed among the members of the team or allocated to a specified team coordinator.

Team Organization and Process Structuring

Before a team can perform its duties, team members must be chosen, tasks must be assigned, and resources must be allocated to and negotiated by team members who will need them to perform their assigned tasks. Procedures must also be developed for using the team's resources and coordinating the work of the individuals within the team. Training may be required to ensure that the team members understand these procedures and use them effectively. Some of the activities in organizing the team and specifying the process it will implement in performing its duties are listed below:

- Staffing
- Resource allocation
- Task assignment
- Procedure development
- Training

Process Monitoring

Once the team begins to perform its assigned tasks, the effectiveness of the process it uses can be assessed over time. Monitoring provides the data needed to manage and support the team during its operations and to suggest process improvements for subsequent operations. Monitoring activities involve the following general steps:

- Gathering data on team activities
- Measuring team progress
- Identifying potential team and process problems

Control and Process Improvement

Since team management is not a static activity, data from monitoring the performance of the team can be used at any time to modify the process used by the team to perform its duties. This management activity identifies or anticipates problems and then focuses and directs the resources of the team to resolve them by modifying the team, the team process, or the team's objectives. These process improvement steps involve the following management and leadership activities:

- Facilitating and focusing communications
- Motivating team members
- Modifying task assignments
- Reallocating resources
- Choosing/rejecting process alternatives
- Modifying goals and procedures

MISSION PLANNING

Mission planning activities define a problem, specify a mission's objectives, and then develop, evaluate and select courses action to be pursued in attaining those objectives. Planning activities involve development of a shared understanding of the problem, setting realistic goals to be pursued, and identifying actions to address the problem. These shared understandings are developed prior to and during the processes of goal setting, action planning, and decision making.

Problem Definition

Upon receiving a mission assignment, the team must develop a shared understanding of the nature of the problem. Since the team is composed of people representing a variety of domains of expertise, some clarification of terms is usually required. Any ambiguity (conflicting information) or uncertainty (incomplete information) may require clarification. Problem definition activities include:

- Study of the problem as presented
- Comparison of views and identification of ambiguities or uncertainties
- Determination of additional information desired and possible sources
- Analysis of causal factors and relationships
- Identification of potential points of intervention/leverage

Mission Goal Setting

Before a plan can be formulated, the mission's objectives must be clarified and any constraints imposed on the conduct of the mission by political, procedural, and tactical considerations must be identified. This planning process involves the following steps:

- Defining goals
- Selecting immediate, mid-range, and long range objectives
- Identifying constraints
- Identifying potential problems

Developing Alternative Courses of Action (COAs)

Once the mission's objectives, constraints and potential problems have been identified, alternate methods for using available staffing, resources, data, and tools to achieve the objectives and resolve the problem(s) can be proposed. This planning process involves the following steps:

- Determining required actions
- Determining expected responses to those actions
- Determining capabilities
- Identifying required staffing, resources and tools
- Scheduling tasks required to perform the selected COA

Evaluating the Alternative COAs

Each alternative COA must be evaluated during the planning process to determine its potential costs and probable outcomes. This planning process involves the following activities:

- Determining COA evaluation criteria
- Determining weights for each criterion
- Determining weighted costs for each COA
- Determining the effect of each COA on other missions

Selecting a COA and Developing Contingency Plans for Changing It

The costs and potential outcomes identified for each COA provide a basis for comparing the alternatives to identify a COA that can achieve the mission's objectives within its cost and tactical constraints. Since mission operations are likely to involve uncertainties, more than one COA may be needed to address mission contingencies. In those cases, procedures and contingency plans for switching to an alternative COA must also be developed. This planning process involves the following activities:

- Comparing COA costs and outcomes
- Choosing the best COA
- Identifying uncertainties and missing data
- Adding contingent COAs to address uncertainties
- Determining selection procedures for choosing contingent COAs

MISSION OPERATIONS

Mission operations involve tasks performed by team members to execute a plan in pursuit of one or more of its objectives. Although these tasks may involve physical manipulations, they also usually

require decisions to be made on when and how to perform those operations. This aspect of the operational activities involves the way that the team collects, organizes, interprets and acts on data required to justify or trigger those physical manipulations. Although these datarelated activities are described in three sequential stages below, they are often performed iteratively so that several cycles of collection and interpretation might occur before a response or interpretation is shared with other members of the team or its external contacts.

Collecting Data

Data must be identified and collected before they can be organized and interpreted. Each member of the team must be able to recognize which data are relevant to that member's tasks. In addition, it may be necessary to recognize, collect and share data useful to other team members. Exemplary activities for collecting data are listed below as possibilities for support to improve the data collection process:

- Locating potential data sources
- Searching each data source for mission-relevant data
- Selecting potentially useful data items
  - Mission progress
  - Dispositions, capabilities, conditions, and threats
- Retrieving the data

Organizing the Data

Once data have been collected, they must be organized according to some sorting scheme and either used or stored for later reference. This procedure usually involves the identification of attributes of the data that enable them to meet specific mission or team requirements. The following three activities are usually performed during the organization:

- Categorizing and filtering the information
- Extracting mission-related attributes
- Storing information by attributes for later recall

Interpreting the Data

Teams performing missions are usually required to interpret the data they collect to determine which of several possible actions to perform. These interpretations include simple attribute recognition, pattern detection and matching, hypothesis generation, and hypothesis testing. Those activities and some of their sub-steps are listed below:

- Identifying patterns or items of interest in the data
  - ♦ Comparing current patterns to stored patterns
  - ♦ Identifying matching patterns, mismatches and missing data
- Generating hypotheses
  - ♦ Relating to historical/contemporary data
  - ♦ Integrating/Understanding/Interpreting/Translating results
  - ♦ Visualizing consequences
  - ♦ Anticipating requirements
- Evaluating/Assessing/Testing hypotheses

Responding

Once the data have been collected and interpreted, the team or a team member may be required to respond in some way to the information or patterns that have been recognized in the data. Responses may range from simple decisions to ignore the data to more complicated actions required to notify someone else, perform an action, or control a process. The following list includes several types of responses that might be required.

- Focusing/Ignoring/Deciding
- Contacting/Interrupting someone
- Telling/Notifying/Reporting/Requesting something
- Replying/Acknowledging a request
- Performing an action
- Starting/Stopping a process

THE C^2W INFORMATION ENVIRONMENT

Many of the C^2W team's activities involve searching, selecting, and processing information. Collaboration between team members occurs whenever someone in the team identifies information useful to the mission and then shares it, or an interpretation based on it, with the appropriate team member(s) at an appropriate time.

Since information is the substance that flows between team members and also the focus of much of the team's activity, the characteristics of that information can be critical to team performance.

INFORMATION NEEDED FOR TEAM MANAGEMENT

Management procedures provide guidance on how to structure the team and coordinate its activities. Although some of the management activities may have been performed during team formation and training (e.g., the roles of team members and some of their tasks may have been determined) data must still be collected and analyzed by team leaders during team operations. These data are used by the leaders to monitor the mission's progress in order to decide when and how to provide the team with direction and support.

Procedures to Follow in Managing the Team

Team management procedures specify the steps to be taken by team builders and team leaders to structure the process used by the team to carry out its mission. These procedures fall into the two categories: (1) planning the process; and (2) monitoring and controlling the process.

Procedures for Planning the Process. These procedures deal with staffing, task assignments, equipment allocations, and other methods for planning how the team will perform and interact. They specify how to plan the process that the team will use to perform its duties, how to allocate tasks, and how to specify the way in which those tasks will be performed.

Procedures for Monitoring and Controlling the Process. These procedures deal with collecting information on the performance of the team, and then using that information to support the team or change the process it follows. They specify what to monitor, what to look for, and what to do in response to that data to direct and support the process used by the team.

Data Required by the Management Procedures

The management procedures (if they exist) specify how the team should be structured and how to monitor the process used by the team to perform its duties. Data on the characteristics of the team and the tasks they will perform provide the information required to execute those procedures.

Data Needed for Process Planning. Since planning the process to be followed by the team involves selecting staff, assigning tasks, allocating equipment, and specifying orders, data are needed about the staff, their abilities and training, the tasks they will perform, and the procedures that they must follow in order to perform their roles/responsibilities. A few examples of data used in each of these areas are provided below:

- Data needed to choose people:
  - Process staffing requirements
  - Individual training and experience

- Data needed to assign tasks:
  - Process load on staff
  - Individual abilities and differences
- Data needed to allocate equipment:
  - Task performance requirements
  - Equipment performance specifications
- Data needed to design and select procedures
  - Task performance requirements:
  - Equipment interface specifications
  - Task communication and coordination requirements

Data Needed for Process Monitoring and Control. Once the team has been structured and tasked, data on the team's performance and potential problems can be used to decide whether the process they are following requires modification or support. General types of data that could be used for process monitoring and control include:

- Data needed to identify problems:
  - Process expectations
  - Process status
  - Process errors
- Data needed to evaluate alternatives:
  - Process constraints
  - Consequences of process changes

INFORMATION NEEDED BY MISSION PLANNERS

Mission planning is built on situation assessment, i.e., definition of the problem, its context, causal factors, and expected outcomes. Based on this situation assessment, mission planning procedures specify how to develop and evaluate alternative courses of action. Those procedures require data to be collected and analyzed during the planning process. The data are used by the planners to specify the mission's objectives and to evaluate the costs and potential outcomes of the alternative courses of action.

Procedures to Follow in Planning a Mission

Mission planning procedures specify how to select mission objectives and then to develop, evaluate and choose alternative courses of action for meeting those objectives. Separate procedures can be used for each of these activities:

- Procedures for defining the problem
- Procedures for setting objectives
- Procedures for developing COAs
- Procedures for evaluating COAs
- Procedures for choosing an appropriate COA

Data Required by the Planning Procedures

During the planning process, data required by the planning procedures must be collected and evaluated. These data provide the basis for suggesting alternative courses of action and also for comparing their outcomes and costs.

Data Needed for Defining the Problem. The mission planning team must acquire data to develop a shared understanding of the nature of the problem. Some data may be internal to the team; other data may be required from external sources. Any ambiguity (conflicting information) or uncertainty (incomplete information) may require clarification. The mission planning team uses the following items to define the problem:

- Problem indicators and data sources
- Additional information requirements and possible sources
- Assumptions and interpretations of the team members
- Analyses by external parties
- Previous experience with similar problems

Data Needed for Setting Objectives. Since planning requires alternative COAs to be generated and evaluated to meet specific mission objectives, data on those objectives must be provided to mission planners. Data will also be needed on mission resources and on any political, time, or performance constraints under which the mission must be performed:

- Mission objectives
- Mission resources
- Mission constraints

Data Needed for Developing COAs. Once the mission's goals and constraints are determined, planners must develop alternate courses of action that are able to meet those goals using the mission's available resources. Data required for this process involve characteristics of the mission, the capabilities provided by the resources assigned to the mission and the problems that the mission will be required to solve to achieve its goals. Some of these data requirements are listed below:

- Mission goals
- Mission domain:
  - Geography
  - Weather
  - Politics, etc.
- Dispositions:
  - Own
  - Others
- Capabilities:
  - Own
  - Others
  - Process
- Expectations:
  - Conditions
  - Behaviors
  - Changes
- Strategy and tactics, or operations to be performed

Data Needed for Evaluating COAs. Once alternative COAs have been developed, they must be evaluated to determine how well they meet the mission's goals and constraints. Data required for this evaluation process include:

- Candidate COAs
- Measures of effectiveness (MOEs) for COA
  - ♦ COA outcome probabilities
  - ♦ COA probable/estimated costs

Data Needed for Choosing a COA. In the final stage of the planning process, a COA must be selected and contingency plans for modifying that COA during mission operations must be developed. Data that support this process are provided by the COA evaluations and estimates of the reliability of the data on which they were based.

- Mission goals
- COA evaluations
- Uncertainties and potential problems

INFORMATION NEEDED DURING MISSION OPERATIONS

Mission operations involve the execution of a mission plan. Operations may involve several teams with different tasking. For any single team or individual, information will be required about the tasks that are to be performed, the performance requirements and the data needed to perform those tasks.

Procedures to Follow During Mission Operations

Operating procedures specify which tasks must be performed to execute the mission plan. Performance requirements may be associated with the procedures, or added later to tailor the procedures to specific missions. Most missions will require data collection and the procedures will specify what data will be needed during the mission, how it can be acquired, and what actions should be taken in response to the data.

Procedures for Search and Collection of Mission-Related Data. These procedures specify where to find the data that will be required during the mission and how to collect it. They provide answers to the following questions that must be answered to perform data collection tasks:

- Where to look (information sources)
- How to look (search procedures)
- How to collect (retrieval procedures)

Procedures for Organizing, Sorting, and Storing Items. These procedures specify how to organize information and store it so that it can be used for mission purposes. They describe how to identify mission-related data, how to sort it into categories, and how to combine individual data items to obtain patterns. Some of the questions answered by these procedures are listed below:

- How to extract data attributes (filtering procedures)
- How to organize the data (patterns and bins)
- How to sort the data (sorting procedures)
- How to save the data (storage procedures)

Procedures for Interpreting the Data. These procedures specify how to match the data to known patterns, how to construct hypotheses, and how to relate those patterns and hypotheses to mission requirements. Some of the questions answered by interpretation procedures are as follows:

- What data to interpret
- What to translate (translation requirements)

- How to translate (translation procedures)
- How to recall stored patterns (retrieval procedures)
- How to compare patterns (comparison procedures)
- How to handle uncertainties and missing data

Procedures for Generating Appropriate Responses. These procedures specify how to respond to the data that has been collected and interpreted. They provide guidance on two issues:

- When to respond (response requirements)
- How to respond (response procedures)

Data Required by the Operations Procedures

Some types of data used during C^4I missions are specified below. They are grouped according to the team activities in which they are used. Some of these data are external items that must be collected by team members. Others are composites that must be built and, perhaps, shared, before they can be used or evaluated.

Data Items to be Collected and Stored. During mission operations, data required to perform the mission, and any information which might require the mission plan, the mission process, or task performance requirements to be modified, must be collected. Some of these items are listed below:

- The mission plan, requirements and constraints
- Data on current conditions:
  - Geography
  - Weather
  - Politics, etc.
- Data on current dispositions:
  - Own
  - Friendly
  - Hostile
  - Neutral
- Data on current capabilities:
  - Own
  - Friendly
  - Hostile
  - Neutral
- Data on current mission status:
  - Status of team, mission and objectives
  - Change history

Information Needed to Filter, Sort and Organize Data. To be useful to the mission, data must be organized and related to mission requirements. Procedures identify how to perform these steps, but data are needed to follow those procedures. Some of the additional data that help in this organizing process are listed below:

- Data reliability estimates
- Data sorting attributes
- Data storage and grouping criteria

Information Needed to Interpret Data. Data interpretation involves detecting and evaluating mission-related items and patterns. Interpretation is a broad topic with a host of potential procedures that can be optimized for specific purposes. Some of the data that might be required by those procedures include:

- Stored patterns
- New patterns
- Pattern matching criteria
- Results of projections and expectations
  - Projected conditions
  - Projected dispositions
  - Projected capabilities
  - Projected outcomes

Information Needed to Respond. Once the data have been interpreted, it may be necessary to respond to the interpretation by taking some further action. Procedures determine when and how to respond, but following those procedures requires data on the procedures themselves and on how to tailor the response to mission requirements. Some of those data items are listed below:

- Response triggering requirements
- Data items to include in response
- Translation or interpretation required by recipient(s)

SUPPORT FOR THE C^2W TEAM

SUPPORT FOR TEAM MANAGEMENT

Management of the C^2W team involves coordination of the team, monitoring the process used by the team to pursue its objectives, and provision of the leadership, resources, direction and focus required to insure that the process used by the team will meet its objectives. Since management deals with the process used by the team, management support involves aids for either monitoring or modifying that process. Features to provide that support could be designed either to provide team leaders with the information they need to perform management tasks, or to improve their performance of those tasks after collecting the information.

Support for Team Coordination and Leadership

The function of choosing the process that will be followed by the team members involves assigning tasks and procedures that the team can perform to accomplish its objectives. As the team performs its tasks, the team leader can help by directing the attention of the team members to mission-specific goals. They can also facilitate coordination among team members by providing communication resources and the incentive to use them. Some features that could be used to support team coordination are listed in the following subsections.

Task, Duty, and Workload Allocation Aids. These aids could either help provide team leaders with the information they need to assign tasks and workloads or they could help them improve their efficiency at managing those workloads. Some examples are as follows:

- Task specification aids
- Individual and team capability measures
- Task allocation guidelines
- Workload estimation and monitoring aids

Procedure Development and Enforcement Aids. Rules and procedures can help to structure the team process by standardizing task performance. This allows the team leaders to compare team results with process expectations and predict the effects of process changes. Aids can either specify the procedures that will to be used or can help team leaders develop and enforce custom tailored/innovative rules and procedures. Some examples of rules and procedures currently in use are listed below:

- Rules of engagement
- Communication and collaboration protocols
- Team positions and responsibilities (e.g., EW, Intel, Crypto)

Communication Aids. Team coordination requires contact between team leaders and team members. Team leaders can be supported by improving either the speed or efficiency of these communications. The same aids can be used to support collaborative communications among team members. Some familiar communication features are listed below:

- Mechanisms for transferring messages/information
- Message composition and editing
- Message storage and retrieval
- Message prioritization

Collaboration and Coordination Aids. Collaboration occurs when one team member recognizes that data in his possession might be of use to another team member, transfers that information or an interpretation of it, and the transferred information is used by its recipient. Support for this process can be provided by the team leader, by the communications network, and by individual team members and their workstations. Support can be targeted at three stages of the collaborative process: (1) making sure that the collaborators recognize data needed by others; (2) streamlining the transfer of that information between members of the team; (3) reducing the time and effort required to correlate, interpret, and integrate shared data. Some examples of features that can help support collaboration are as follows:

- Attention focusing:
  - Reminders
  - Requests
  - Warnings
  - Response priming
- Shared workspaces:
  - Shared displays and visualizations
  - Shared editing and annotating
  - Shared databases
- Conferencing
  - Contact and meeting scheduling
  - Mediation
  - Feedback mechanisms and protocols

Support for Process Monitoring

Once the process used by the team to perform its tasks has been started, team leaders may also be tasked with monitoring that process and changing it in response to changes in mission or team requirements. Some features that could help in monitoring the team's activities are as follows:

- Process status indicators
- Team workload indicators
- Process measures of effectiveness (MOEs)
- Process alarms and alerts
- Security status indicators

SUPPORT FOR MISSION PLANNING

Once the team is formed it will be given specific mission-related tasks. Mission planning is the task performed to assess the situation, define the mission's goals, and devise and evaluate plans to meet those goals.

Support for Problem Definition

The first step in mission planning is to define the problem by performing situation assessment. This involves marshalling available information, determining any patterns, relationships or trends, and constructing the most plausible interpretation(s). The final step is to determine possible mission implications with regard to what is desirable and possible as well as implications for resource requirements to accomplish the mission. Features which could be used to support problem definition would help the team gather and interpret relevant information about the problem/threat, including:

requirements to accomplish the mission. Features which could be used to support problem definition would help the team gather and interpret relevant information about the problem/threat, including:

- Locations and movements of hostile, neutral, and friendly forces
- Size and types of various forces
- Intelligence regarding intentions
- Political background and context
- Focus internal or external team expertise on interpretation of information
- Formulating a shared assessment by interaction among team members

Support for Goal Setting

The next step in mission planning is to identify the mission's objectives, resources, and constraints. If the team's goals have been pre-specified, then the team must work out a common understanding of the meaning of the mission goal(s), i.e., what is included and where the boundaries lie. Based on this shared understanding of the goal(s), information support requirements can be specified as listed below. If the team sets its own goals, then further information support may be required to identify suitable objectives and to determine both the resources that will be available during the mission and any constraints that will be required for the use of those resources. Features that could be used to support goal setting would help the team locate and use the following information:

- Overall campaign objectives specifications
- Mission coordination requirements
- Political constraints
- Target selection criteria
- Target prioritization schemes

Support for COA Generation

The next step in mission planning determines alternate COAs that could be used to achieve the mission's goals. Support focused on COA generation might include aids for each of the activities discussed briefly below.

Requirements Analysis. Stated goals and objectives must be translated into specific mission requirements and then detailed as a list of resources with sequential tasks that can be performed during mission operations. Examples of features that could be used to support requirements analysis might include:

- Mission resource specification aids:
  - Records of resources from previous missions
  - Resource specification formulas
- Task specification aids:
  - Records of tasking for similar missions
  - Task specification protocols
- Contingency plans

Capabilities and Deployment Assessment. Since the mission plan implicitly projects how organizational resources will be used to achieve the mission objectives, the capabilities of those resources, and the capabilities and dispositions of expected opposition forces, must be identified and assessed. Features which could be used to support this assessment include:

- Deployment assessment aids

Logistical Analysis and Planning Aids. Since a mission often involves transporting men, materials, and information from an assembly point to where they will be used, the mission plan should include estimates of this transport operation and the effect that it and its uncertainties might have on the mission. Features that could be used to support planning of mission logistics include:

- Resource location finder
- Transport timetable estimator
- Transport capacity and efficiency estimator
- Competing transport demand indicators

Timeline Development Aids. Once the mission's objectives and the resources and capabilities available for meeting those objectives have been identified and evaluated, mission timelines for alternative COAs can be specified. Some features that might help in timeline development include:

- Task preparation time estimator
- Mission task timing estimation and display
- Supply delay estimation and displays
- Workload and capability estimation
- Task sequencing aids

Mission Domain Evaluation Aids. Terrain and weather can change a mission's requirements and modify the timeline developed for meeting those requirements. Some features that could be used to help evaluate the domain and conditions in which the mission will be carried out include:

- Mission-related meteorological forecasts and weather reports
- Displays of oceanographic charts and measurements
- Maps and other terrain displays and representations

Support for COA Evaluation

Once alternate courses of action have been suggested, planners evaluate them to compare their costs and their potential for success. These activities involve estimating costs and effects based on current information and history as well as developing MOEs of each alternative. COA evaluation could be supported by several performance aids.

Historical Analysis and Projections. Memory or records of prior operations can be used to estimate the costs of a particular COA and to suggest its probable results. Support for such analyses and projections can be provided by maintaining a database of historical results and providing a mechanism for the user to access and tailor database contents to current needs. Features intended to support analysis based on historical data might include:

- Records of prior COA costs and results
- Mechanisms to estimate alternative COA costs and effects based on those records

COA Comparison Aids. Once the projected costs and effects of several alternative courses of action have been calculated, the alternatives can be compared to determine which provide the best fit to mission requirements. Aids which could support COA comparison would incorporate features that either helped to develop the basis for the comparison by assigning weights for different costs and effects, or which helped to calculate and display the results of such a comparison. Some examples of these COA comparison features might include:

- MOE development aids
- MOE calculation aids
- MOE comparison aids

Support for COA Selection

The final step in the planning process requires the team to select one or more COAs to serve as primary and contingency plans for the mission. The COA evaluations provide much of the data required for this process, so aids designed to support COA selection are expected to be focused on how that data can be used to develop the mission plan. Some areas in which aid might be provided are listed below.

- Risk analysis
- Readiness assessment
- Coordination requirements and advance notices to parties involved

SUPPORT FOR COLLABORATIVE INFORMATION PROCESSING

During both the planning and operational phase of a mission, the team must collect and interpret information so that potential threats to the mission can be identified and appropriate responses can be suggested to either eliminate a threat or limit its potential consequences.

Support for Information Needs Tracking

Information relevant to the mission must be recognized before it can be collected and interpreted. If the team is to collaborate, then each team member must be aware of the needs of other members so that information that meets those needs can be collected and transmitted to those that have a use for it. Support for needs tracking might include the following features:

- Information needs predictions
- Information requests
- Collection status indicators
- Task status indicators for individual team members

Support for Information Collection

Once the team's information needs are recognized, data which meet those needs must be located and collected. Support for information collection could be provided by the following features:

- Data search mechanisms
- Mission information identification aids
- Data capture mechanisms

Support for Information Organization

Whenever data which meet mission needs are collected, they must be categorized and handled according to the particular use they will have during the mission. Support for information organization could be provided by the following features:

- Information categorization aids
- Information attribute assignment aids
  - Annotations
  - Highlighting

- Information storage and retrieval by attributes

Support for Individual and Joint Information Interpretation

Once mission-related data have been collected and organized, they must be interpreted to evaluate their relationship to the mission and its objectives. Support for interpretation might include some of the following features:

- Multi-member interaction aids:
  - ♦ Shared visualization aids
  - ♦ Shared workspaces
- Mission data expectation templates:
  - ♦ Expected values
  - ♦ Expected ranges
  - ♦ Range limits
- Visualization aids:
  - ♦ Mapping and geographical representation of positional information
  - ♦ Situation status displays
  - ♦ Capability displays
- Information reliability assessment aids:
  - ♦ Information reliability coding
  - ♦ "Circles of uncertainty" for positional data

Support for Information Integration and Correlation

Some aspects of C4I require that data collected from different sources be combined in order to generate and test hypotheses about the mission and its progress. Support for the fusion or linkage of data elements might include some of the following features:

- Pattern creation aids
  - Track history displays
  - Pattern templates
  - Missing data flags and indicators
- Pattern comparison aids
  - Aids for identifying information which supports or invalidates alternate hypotheses
  - Aids" for identifying the effect of uncertainties on derived patterns and values
- "What-If" projections
  - Projected positions and capabilities
  - Projected effects of uncertainties

SUPPORT FOR RESPONDING AND REPORTING

In addition to the collection and analysis of mission relevant data, the C^2W team is expected to recognize data that must be shared with others outside the team and to recognize and act on patterns of data that suggest potential threats to the mission's objectives. Support for the team in choosing an appropriate response can involve either aids which help to determine when a response is required or those which help to tailor the response to the mission's requirements or to the recipient's needs.

Response Triggering

Before a team member can respond or report, he or she must recognize that a response is required. Aids for triggering a response might entail some of the following features:

- Response history
- Next or usual response reminders
- Response time window indicator

Information Assembly Aids

Response in C4I often entails assembling information that explains or describes the response. If the response initiates an action, such as launching a missile or performing an activity, then the specific steps that must be taken to perform the response must also be identified. Aids for assembling that information might include some of the following features:

- Report or action requirements
- Methods for identifying potential supporting data and contraindications
- Access aids to help collect information required by the response or report

Information Translation and Integration Aids

Since the response might require information to be translated into a form that can be used by other recipients, some of the features described in the following subsectionscould be used to help with those translations.

Data Translation Requirements and Protocols. These aids could either identify the translation requirements, or, by coding the requirements in software or hardware, could perform translations for:

- Specific types of data
- Specific missions
- Specific recipients

Data Integration Requirements and Protocols. These aids could either specify how to integrate data for different purposes, or could help perform integrations for:

- Specific types of data
- Specific missions
- Specific recipients

Report Generation Aids

Some reports may require substantial effort to organize and present the data that triggered the report. The following features might be useful to support report preparation:

- Text editing
- Drawing
- Plotting
- Annotating and highlighting
- Report organization aids

COMMERCIAL OFF-THE-SHELF COLLABORATION TOOLS

The first commercial off-the-shelf (COTS) collaboration tools considered in this evaluation are those that were designed to facilitate collaboration among group members. These tools run on a network, permitting people to communicate and to contribute, access, and modify shared information. Since these features are similar to those required in C^2W team collaboration, the techniques developed for COTS collaboration tools to support commercial collaborative environments are of great potential interest to this project.

The objective of a collaborative environment is to enhance the productivity of a team. Commercial collaborative environments include people, personal productivity tools, network, groupware, and procedures or practices used to connect them and coalesce them into an adaptive, problem-solving team.

The computers in the collaborative environment can function either as communications tools or as personal productivity tools for individuals in the group. As productivity tools, they can also be used to support standardized procedures and practices according to which individuals perform their assigned tasks and the group carries out its interactions. In other words, the collaborative environment provides a structure for task accomplishment and team interaction. That structure may be more or less facilitative of team performance.

Military C^2W teams operate in collaborative environments that require efficient, accurate, and rapid situation assessments in order to identify potential problems and to create and evaluate alternative courses of action (COAs). Collaborative tools that support these activities can provide the features mentioned above. The features of collaborative tools are briefly summarized below.

COLLABORATIVE STRUCTURES

These tools provide the framework for collaboration between individuals. Although other tools are used for the mechanics of communication, the collaborative structure determines who will communicate with whom, when communications can occur, communication protocols, and the general content and focus of group interactions. Common methods of structuring a group involve designation of a mediator to assign tasks and control group interactions or the incorporation of the mediator's function in a set questions, procedures, or constraints designed to focus the group's attention and direct its progress toward some goal. Collaborative structures determine when communications will be synchronous (conferences, phone calls), and they can dictate the delays experienced in asynchronous communications (mail, reports). Structure may be imposed on a group by limitations and capabilities of collaborative tools, by software mediators, or by procedures which operators are trained to use in communications. The features and limitations of various approaches to providing collaborative structure are summarized in table 1 and discussed below.

Mediator (Team Leader)

A team leader can provide all of the structuring features, at a low to medium load on the team, but at the high cost of adding the mediator's duties to the leader's task load. Otherwise, mediation may devolve on team members as a collateral duty or implicit requirement at the cost of diverting attention from other tasks. Team performance can be optimized by training the leader and supporting team structuring functions. Performance can be expected to vary depending on the differences

between individual mediators and competition for attention and time resources. Other products attempt to provide the support without the mediator.

Table 1. Collaborative structure features and limitations.

Features Provided	Mediator	Training in Procedures	Workflow System	Comm Network	Message Protocols	Checklists
Task Assignment	•	may			•	•
Task Scheduling	•	may	•			•
Performance Standardization	may	•	may		•	•
Process Reminders	•	may	•			•
Message Routing	•			•		
Leadership and Focus	•					
Process Monitoring	•		•			•
Workload Adjustments	•		•			
Time						
Synchronous	•			•		•
Asynchronous		•	•	•	•	•
Delay	seconds	varies	varies	varies	varies	seconds
Costs						
Load on Users	low-med	med	med	varies	low	low
Cost to Provide	high	med	high	varies	low	low

Training in Performance Procedures

Procedures, when followed, provide performance standardization and can provide task assignments, scheduling, and process reminders. They do not provide leadership, focus, process monitoring, or workload adjustments, although they can help to standardize those features between mediators.

Workflow System

Workflow systems provide assistance in scheduling tasks and in adjusting workloads. They usually include some sort of process monitoring to help determine when adjustments may be needed. The system can either be used to support a mediator or to distribute parts of the mediation task between other members of the team.

Communications Network

A communications network provides a mechanism for routing messages between team members. While the network can provide the path for messages to flow between users, it must be combined with some sort of addressing and messaging features to provide the same features provided by a mediator. A network provides one way in which mediator tasks can be supported to reduce demand on the mediator and either lower the mediator's workload or distribute it between team members.

Message Protocols

Message protocols can be used to structure the collaborative process by limiting or focusing communications between team members. Since protocols are usually trained prior to operations, they exert only a minimal load on the team, but may entail training costs.

Checklists

Checklists allow team members to anticipate process requirements and to monitor whether those requirements have been met. They are usually produced asynchronously and used synchronously, making them more suitable for predictable processes than for novel or unknown ones. They provide an external memory for process requirements that can be used to support the mediator or individuals at the cost of the attention and time required to keep them up to date. Unfortunately, although the load to make a checkmark is low, the optimum time to perform an update is often when individual resources for the update are unavailable since they may be needed for the task itself rather than for recording its completion.

COLLABORATIVE WORKSPACES

These tools provide a shared workspace that can be used by group members. Collaborative workspaces can involve co-authoring of documents, a whiteboard for graphics, or any other task-oriented workspace that can be shared and modified by group members. Some method for identifying the contributions of individual group members (e.g., color-coding) is often provided. If the workspace allows two or more individuals to modify the same item within the workspace, then some mechanism must determine which modification will prevail. This mediation mechanism may be provided by either the workspace itself, or a collaborative structure imposed on the workspace by a chain of command or other procedural protocol. Mediation is particularly important in distributed structures where it is possible for members to have different versions of a document. In those situations, changes made by one individual may not appear in all copies. The features and limitations of various alternative workspaces are presented in table 2.

Shared Databases

Shared databases allow one person to store information and another to retrieve it. They support attributes to organize data and editing to annotate entries and identify authorship. Databases support asynchronous storage and retrieval with minimal delays, but generally make no provision for simultaneous interactions between team members.

Shared Whiteboards

Whiteboards provide graphical workspaces that can be used either synchronously or asynchronously to share pictures, drawings, and text. Entries can be color coded to identify authors, but no underlying organization is provided beyond that which might be imposed by usage protocols.

Table 2. Collaborative workspace features and limitations.

Features Provided	Shared Database	Shared Whiteboard	Co-Authoring	Text Conference	Audio Conference	AV Conference
Entry and Display						
Text	•	•	•	•		
Pictures	•	•	•		•	•
Sound			•		•	•
Graph Plotting	•					•
Drawing and Pointing		•				•
Annotating/Editing	•	•	•			
Author Identifications	•	•	•	•		•
Storage and Retrieval						
Text	•	•	•	•		
Pictures	•	•	•			
Sound	•		•			
Sorting						
Interrupts or Arrival Flags		•		•	•	•
Attribute Bin Creation	•					
Sort/Retrieve by Attributes	•			•		
Revision Tracking	•		•			
Time						
Synchronous		•		•	•	•
Asynchronous	•	•	•	•		
Delay	seconds	seconds	minutes	varies	seconds	seconds
Costs						
Load on Users	med	med	med	med	high	med–high
Cost to Provide	med	high	med	med	low	high

Co-Authoring

Co-authoring systems provide a mechanism for editing text and tracking revisions made to that text and its associated illustrations by team members. The workspace is usually asynchronous since revisions are usually passed sequentially between team members during the authoring process.

Conferencing

Conferencing systems provide for the synchronous exchange of information between different members of a team. Some provide storage and retrieval of transmitted information, while others (e.g., audio conferencing) require participants to remember prior interactions and responses. Text conferencing can either be synchronous (chat boxes) or asynchronous (bulletin boards). Audio-visual

conferencing supports distributed meetings by providing audio links as well as visual images of spatially distributed meeting participants.

MESSAGE SYSTEMS

These tools provide a mechanism for group members to contact each other and then send, receive, or reply to messages. Messages may be synchronous (meetings, phone calls) or asynchronous (mail, fax, bulletin boards, news groups). Many of the tools identify the author of each message and the time at which it was sent. Some also provide logging of when a message was received and notification to the sender when it is read. Video tools provide images of conferees as they speak or link images of a speaker with stored audio so that messages will retain the visual cues that are available during face-to-face meetings. Bulletin boards provide two features. The boards maintain a message server that can store addressed messages, text, or pictures in a structured database. They also permit clients to share information with strangers by searching the database for titles, content, and other stored information. News groups provide a structure for messages that includes categories for messages and the ability to subscribe to a category and then receive all new messages posted within that category.

Message systems operate independently of the medium used to transmit the messages, but most tend to support features required by the principal users of their transmission medium. Some of these transmission media, like the Internet and large local networks, connect thousands of users over vast distances. They can be used to collaborate with people distributed in space with whom it would be difficult or impossible to meet locally, with those whose duties or work cycles prevent direct synchronous communications, or with those whose existence or expertise was unknown until they responded to a broadcast message requesting consultation. The features and limitations of various message systems are summarized in table 3.

Package Mail

Package mail provides a mechanism for transporting text, graphics, sound, or anything else that can be included in a letter or other small package. Collaboration using package mail is usually sequential between pairs of collaborators. Significant delays or losses can occur if distances are large or transmissions are intercepted. The load on users tends to be significant since addressing, packaging and broadcasting require user time and effort. Costs reflect the cost of the transportation network.

Courier

Couriers provide most of the features of package mail at a higher speed and lower load on users. Couriers can also add interrupts, immediate forwarding and rerouting, package tracking, and potential for delivery to individuals rather than mailboxes. Couriers are more expensive than existing transportation networks, but can be economical over short distances or combined with existing networks to reduce transportation costs.

Electronic Mail

Electronic mail provides message transport at high speed over existing networks. Load on users is moderate and, like other mail systems, can be adjusted to workload demands since messages can be stored until they are ready to be sent or read. Costs for electronic mail vary depending on the existence of networks and the computer facilities required to provide interrupt, storage, and routing features. Since electronic mail transmits copies of messages rather than original documents,

broadcast and forwarding are simplified, but transport of original documents and packages is not supported.

Table 3. Message system features and limitations.

Features Provided	Package Mail	Courier	Electronic Mail	Telephone	Fax	Voice Mail
To Sender						
Message Addressing		•	•	varies	varies	some
Message Broadcast			•	•	•	
Copying and Routing		•	•		•	
Message Prioritization			•			
Receipts/Tracking		•	•		•	
Message Editing			•			
To Receiver						
Interrupt		•	•	•	•	
Receiver Locating		•				
Message Arrival Flag		•	•		•	•
Message Logging			•		•	•
Message Sorting			varies			
Message Storage	•	•	•		•	•
Message Forwarding	•	•	•			
Content						
Text	•	•	•		•	
Graphics	•	•	•		•	
Sound		•		•		•
Time						
Synchronous				•		
Asynchronous	•	•	•		•	•
Delay	days	hours	minutes	seconds	seconds	varies
Costs						
Load on Users	med	low	med	high	low	med
Cost to Provide	varies	high	med	med	med	med

Telephone

Telephone provides synchronous communication between individuals or groups. Time delays are minimal, but no storage is provided, so message transfer requires the simultaneous participation of the sender and all potential receivers. This places a very high load on users, since other tasks must be interrupted before communication can take place, and attention must be allocated during the entire exchange interval rather than at the discretion of the recipients. The high attention requirement

provides an efficient alerting and interrupting mechanism and helps reduce costs since the user's memory and attention are substituted for computing facilities. Cost for providing voice communications across existing networks can be low, although training and communication protocols are often required to prevent communications overload for the users, and to reduce the "phone tag" interval while users wait for synchronization to be achieved.

Fax

Fax uses synchronous communication between computers to provide asynchronous transport of images between people. Instead of transmitting documents or pictures, Fax machines copy the visual appearance of the objects to be transmitted and then transmit images of those objects over telephone lines. Synchrony is required between fax machines, but not between users since the receiver prints a copy of the received images which can be read or viewed anytime after its arrival. Limitations include the quality of the copied images, the bandwidth and time required to transmit images, the time required to print copies, and the synchronous nature of the transmission that prevents other messages from being processed during the interval required to receive and print each transmission.

Voice Mail

Voice mail adds asynchrony and storage to telephone communications. It requires a higher load on senders to compose effective messages without feedback from recipients and can introduce substantial delays or losses since messages can be ignored by recipients. Voice mail differs from electronic mail since messages must reach the receiver in order to be stored and must then be composed, with minimal editing, during a limited synchronous connection between the sender and the voice mail system. Voice mail can be combined with telephone communications to provide acceptance, storage, or synchronization of voice messages at the option of the recipient.

SCHEDULING AIDS

Scheduling tools provide a mechanism for scheduling conferences between group members. They also can be used to specify the timing of tasks that must be performed and to remind team members of events that are scheduled to take place. Some of these tools can be used by either a mediator or a team member to produce, categorize, sort, share, annotate, and update to-do lists, timelines, communications directories, and other schedule-related items. Some scheduling aids also provide time tracking and interrupts to alert team members about scheduled events. Table 4 summarizes the features and limitations of several categories of message systems.

Workflow Systems

Workflow systems can help support task and workload scheduling for well-defined tasks and process structures. They provide a record of completed tasks, but they can impose a significant load on users who are required to enter and update items during the process. Automated entry and updating can reduce this load for processes with predefined tasks and schedules. Costs and delays vary depending on process automation and the resources provided for data entry.

Table 4. Scheduling aid features and limitations.

Features Provided	Workflow Systems	Calendars	List Managers	Contact Managers
Task Lists	•		•	
Task Scheduling	•	•		
Task Sequencing	•	•	•	
Reminders		•	•	
Task Completion Records	•	•	•	
Addresses				•
Contact Logs		•	•	•
Contact Notes		•		•
Time				
Synchronous				
Asynchronous	•	•	•	•
Delay	varies	seconds	seconds	seconds
Costs				
Load on Users	varies	med	low–med	med
Cost to Provide	med	med	med	med

Calendars

Calendars can also be used to schedule time for tasks and to provide reminders when a scheduled task must be started. They display tasks in sequential order based on dates and times of day that have been scheduled for task performance. They can be used to track progress and task completion, but generally provide a record of intentions, rather than accomplishments, since there may be no connection between the schedule and actual events. Delays are usually short, but the load on users to keep the calendar updated can be significant. Costs are generally low, although shared calendars require a network and computing facilities or some form of direct access so that users can perform entries and updates.

List Managers

List managers can also be used to schedule tasks and to provide reminders. They differ from calendars by supporting prioritization of tasks and by providing some means for sorting and displaying tasks by their priorities or categorizations rather than their time schedules. Like calendars, delays are generally short and costs depend on the degree of automation and networking required for entering new tasks and marking those that have been completed. Since a list of tasks does not generally require scheduling between collaborators, list managers can impose less of a load on users than calendars, and can be produced at the same or somewhat lower costs.

Contact Managers

Contact managers can be used to schedule and record meetings or other communications between team members. They often support storage of addresses and logs of contacts made, required, or attempted, as well as notes about each contact. Delays and costs depend on the degree of automation provided. Highly automated systems allow automatic or asynchronous entry of contact addresses and notes in order to reduce delays and usage burdens when contacts are initiated or reestablished.

PRODUCTIVITY AIDS

Productivity aids are designed to improve personal productivity in either individual tasks or group activities. Visualization aids can help individuals interpret shared data by translating information into a form that is useful to team members with different areas of expertise. A distributed workspace can sometimes be enhanced through implementation of a mechanism to reduce the time required to compose and transmit messages and route information between team members. Since team performance is usually dependent on the performance of each team member, a distributed shared memory can reduce the time needed to transfer information and, thereby, increase the time available for collaboration. Table 5 summarizes the features and limitations of various productivity aids.

Table 5. Productivity aid features and limitations.

Features Provided	User Interface	Memory Aids	Visualization Aids	Pattern Matching Aids	Brain-storming	Voting
Data Translation			•	•		•
Attribute Highlighting	•	•	•		•	•
Plotting	•		•	•		•
Curve Fitting			•	•		
Pattern Memory	•	•		•		•
Reference Patterns	•	•	•	•		•
Pattern Priming	•	•	•	•		•
Fit and Weight Calculations				•		•
Alternate Hypotheses					•	•
Hypothesis Testing						•
Annotation	•	•	•	•		
Editing	•			•		
Time						
Synchronous	•		•	•	•	
Asynchronous	•	•	•			•
Delay	varies	varies	seconds	varies	seconds	varies
Costs						
Load on Users	varies	med	low	low–med	med	low–me
Cost to Provide	med	med	med	varies	med	med

User Interfaces

User interfaces can be designed to include productivity aids for both the individual and the team. They can reduce the load on the individual users so that more time is available for collaboration. They can also be designed to incorporate memory and interpretation aids that structure and focus the collaborative process. Interfaces with memory to retain images can be used asynchronously or synchronously. The interface load on users can vary from minimal up to a significant portion of the user's capacity. Significant savings can be realized during production by standardizing the interfaces. If, however, the interfaces are inefficient or overly complex, these production cost reductions may be offset by the substantial training costs required to fit the users to the interfaces rather than fitting the interfaces to the users' needs.

Memory Aids

Memory aids can be used to capture information and retrieve it for later use. They have the advantage of being able to store information already in an external system without the danger of errors in translation or degradations involved in storing and retrieving data from human memory. Some memory aids can produce significant storage and retrieval delays and usage burdens when users are required to access their contents.

Interpretation and Decision Aids

Some groupware tools are designed to help individuals interpret patterns and make decisions using information distributed among group members. Visualization and pattern matching aids can be used by individuals or the group to help store and identify patterns or to recognize data attributes. Brainstorming aids are designed to aid decision making by formalizing the process by which alternate hypotheses are created and evaluated. Voting aids are designed to provide simple tallies about group opinions. Pattern matching aids tend to narrow the focus of the group to a few shared patterns, while brainstorming aids tend to broaden the focus of individuals by exposing them to alternate possibilities. Implementations of these features determine their load on users and their costs. Synchronous aids for pattern matching and brainstorming can be particularly time consuming if all team members are required to participate.

SUITABILITY OF COMMERCIAL GROUPWARE FOR SUPPORT OF COLLABORATIVE INFORMATION PROCESSING BY C^2W TEAMS

The section, "Support for the C2WTeam" identified 90 support capabilities of collaborative tools that were determined to be of potential utility in supporting C^2W activities. Several of these capabilities involved initial team structuring, task assignments, and mission planning activities. Those uses of groupware, albeit interesting, do not come within the domain of this study. In addition, existing support features were identified in commercial groupware products. Each individual product provides a different combination of collaborative features. Each product can be characterized by the features it provides, the time window in which those features are available, and the load it places on users who wish to utilize the product's features. What remains to be answered is the question of whether the features provided by the groupware are those needed by the C^2W team.

The following sections compare the features provided by the commercial groupware products with those which have been detailed earlier as potentially desirable features for coordinating and supporting operations of the C^2W team during collaborative information processing. Two types of support will be considered: a groupware product can either provide a feature directly, or it can provide a mechanism that can be used in combination with features in another product to construct that feature.

TEAM MANAGEMENT AIDS

Message Systems

Message systems provide the mechanism for coordinating the team and for monitoring its performance. Some also provide features that either directly support or can be combined with other features to provide support for specific coordination and leadership activities. Table 6 lists potential team management support features and indicates whether those features are directly provided (•) by specific groupware products or can be constructed using features provided by the product in conjunction with other added items.

Table 6 shows that each message system provides some communication features needed for supporting team coordination, but that message systems themselves provide only indirect support (dependent on the content of their messages and their delivery points) for focusing attention and monitoring team performance. Package mail systems and couriers provide similar support, except that it is possible to interact with a courier to ask questions and receive answers. This interaction possibility can be used to focus the attention of either the sender or the recipient about potential process delays or problems. Telephone and picture phones also provide similar support, with their utility dependent on the content of the messages they transport. Picture phones can provide the opportunity for passing more information in a shorter time, with less user interaction, since they provide a visual channel in addition to the audio channel. The utility of this higher bandwidth is noted in the table by the picture phone's ability to support passive process monitoring of the users and their environment from the receiving side of the video link. Audio systems can provide the same level of support for process monitoring only in combination with message protocols that require messages on the process to be composed and transmitted. Although e-mail and package or courier mail systems provide support for asynchronous message editing, transmission, and receipt, only e-mail systems provide all of these features in a single package. The package and courier systems

generally require that the messages be composed using some mechanism outside that provided by the transport mechanism.

Table 6. Team coordination support provided by commercial message systems.

Support Feature	Package Mail	Courier	Telephone	Voice Mail	E-mail	Picture Phone
Message Systems						
Transfer Mechanisms	•	•	•	•	•	•
Direct Delivery to Addressee		may	•		•	•
Composition and Editing	some	some			•	
Storage and Retrieval	some	some		•	•	
Prioritization	some	some	some	some	•	some
Attention Focusing Mechanisms						
Reminders		some	some			some
Requests	some	some	some	some	some	some
Warnings		some	some		some	some
Message Arrival Alerts		may	•	•	•	•
Message Status Lists					•	
Response Priming		some	some		some	some
Process Monitoring Aids						
Process Status Indicators	some	some	some	some	some	•
Team Workload Indicators			some			•
Process MOEs						
Process Alarms and Alerts		some	some	some	some	•
Security Status Indicators						•

Scheduling Systems

Scheduling systems provide a mechanism for both assigning tasks and for monitoring their performance. Table 7 lists potential team scheduling features and indicates whether those features are directly provided (•) by specific groupware products or can be constructed from features provided by the product in conjunction with other added items.

Table 7 shows that although none of the scheduling aids provide complete features that are likely to support C^2W team performance, several of them could be combined with other support systems to provide some of those features. In particular, the scheduling systems tend to provide temporal mechanisms for organizing, scheduling, and reminding about previously scheduled tasks, but lack

support for identifying which tasks should be assigned to C2W team members, or for prioritizing those tasks according to mission requirements other than their time constraints.

Table 7. Team coordination support provided by commercial scheduling systems.

Support Feature	Workflow Systems	Calendars	List Managers	Contact Managers
Workload Scheduling				
Task Specifications	some		some	
Team Capability Measures		some		some
Task Allocation Guidelines	some		some	
Task Prioritization	some	some	some	
Workload Allocation	some	some	some	some
Attention Focusing Mechanisms				
Reminders	some	some	some	some
Requests				
Warnings				
Response Priming	some	some	some	some
Process Monitoring Aids				
Process Status Indicators	some	some	some	some
Team Workload Indicators	some	some	some	
Process MOEs				
Process Alarms and Alerts	some		some	
Security Status Indicators				

SUPPORT FOR INFORMATION PROCESSING

Information must be selected and assembled by individuals before it can be shared with the group. Table 8 summarizes individual information processing features provided by commercial groupware products in categories that would be useful to a C2W team member during mission operations.

This table shows that the commercial groupware provides partial or complete support for several features in the information processing categories. It does not indicate which features of the groupware support each category, and it provides no information on the efficacy of the groupware's support or its ease of use.

Table 8. Individual information processing support provided by commercial groupware.

Support Category	Mediation	Confer-encing	Co-Authoring	Shared Database	Shared Displays	Brain-storming	Voting
Information Needs Tracking Aids							
Information Needs Predictions	some	some		some	some	some	some
Information Requests	•	•	•		some	•	•
Collection Status Indicators			some	some	some		some
Information Collection Aids							
Data Search Mechanisms	some	some	some	•	some	some	some
Mission Data Identification Aids	•	•			•	some	
Data Capture Mechanism	•			•	•		•
Information Organization Aids							
Information Categorization Aids	•	•		•	•	•	•
Attribute Assignment Aids	•	•		•	•	•	•
Sorting by attributes				•		some	some
Storage and Retrieval by Attributes	•	some	some	•	•	•	
Information Interpretation Aids							
Mission Expectations Templates							
Visualization Aids					•	some	
Reliability Assessment Aids		some		some		some	
Information Linkage and Correlation Aids							
Pattern Creation Aids				•	•		some
Pattern Comparison Aids				•	•		
"What-If" Projections	•				some	•	

SUPPORT FOR COLLABORATION

Collaboration requires data to be shared and processed jointly as well as collected. Table 9 shows collaborative features provided by commercial groupware in four categories. The first category involves features which support triggering a response to share information. The others involve the assembly of that information, translation of it for the recipient, and the fusion of information from different individuals in the team.

Table 9. Collaborative support provided by commercial groupware.

Support Category	Mediation	Conferencing	Co-Authoring	Shared Database	Shared Displays	Brainstorming	Voting
Triggering Mechanisms for Sharing							
Information Need Predictions	some	some	some	some	some	some	
Information Requests	•	•	•	•	•	•	•
Meeting Scheduling	some	some	some	some	some	some	
Feedback Protocols	•	some		some	some	some	some
Annotations and Reminders	•	some	some?		some	some	
Response Time Windows					some		
Information Assembly Aids							
Report Requirements	some	some	some	some		some	
Supporting Data Flags	some	some	some	some	•	some	
Integrated Visualization of Assembled Information		some	some		most		
Information Translation and Correlation Aids							
Shared Visualizations	•			some	some		
Translations	•			some	some		
Pattern Templates				some	some		
Model Projections							
Revision Tracking			some				
Report Generation Aids							
Text Editing			•				
Drawing		some	•		some		
Plotting				•			
Annotating or Highlighting			•	•	•		
Report Organization Aids	some		some		some	some	

DISCUSSION

Collaborative software tools have the potential to improve the process and the results of team collaboration. As with any tools, however, there is a cost involved in their use that must be balanced against any potential benefits. We have attempted to analyze these potential benefits by noting which tool features could be used to support specific team activities. This allowed us to group the tools by the support that they provided for team activities and then to contrast that support with the burden that using each tool would place on team members.

Command and control warfare (C^2W) teams are composed of individuals with expertise in diverse warfare specialties involving intelligence, communications, cryptologic analysis, and electronic warfare. We identified three functional domains in which collaborative software could be used to support such a team. Each domain corresponds to a separate aspect of a military operation. In the first domain, Team Organization and Management, we were looking for ways in which the technology could be used to supplement existing procedures for structuring and guiding interactions between team members. In the second domain, Mission Planning, we looked for ways in which the technology could be used to help the team specify mission goals and coordinate resources to meet those goals. The third domain, Operations, encompassed the tasks performed by the team to execute a mission plan and monitor the progress of the mission. The recognition that a team might need different kinds of support for different activities allowed us to identify features of the tools that were appropriate for each domain. We assessed the level of support provided by each tool and the burden that it placed on the team by competing for the team members' time and attention. Since team performance can be enhanced by improving either individual task performance or the team's interactions, both were considered and evaluated.

The complexity of military operations guarantees that useful applications will be found for almost any tool. That same complexity also suggests that there will be other instances in which the same tool will be inappropriate. We have attempted to identify some of those instances by matching features in the tools with features needed to support a team as they perform various components of their mission responsibilities. Recognizing that a team has both collaborative and individual information processing requirements that impact the quality of the outcome, we felt compelled to estimate the load that using each collaborative feature might place on the team and its members. This load is real, and can either become excessive or can be managed and controlled so that the load placed on team members is balanced by its impact on performance outcomes.

CONCLUSIONS

• Since collaborative software has been developed for different purposes and for different end users than those encountered in C^2W, they provide only partial support for C^2W tasks. Current tools were designed to facilitate collaboration itself rather than to provide collaborative support for individuals performing C^2W tasks.

• This partial support can be problematic, since the primary function of the C^2W team is not to transfer information, but rather to acquire, filter, assemble, and interpret it. Time and mental resources spent on the mechanics of the collaborative process therefore can reduce the human resources (time, attention, memory) available for gathering and processing information.

• Several of the tools provided useful features for transferring information between team members. The ability to exchange documents from geographically distributed locations, and the option to use various asynchronous modes of communication that do not require the simultaneous attention of all participants were particularly attractive.

• Scheduling capability is especially critical for achieving coordination among the team members and others involved in planning and execution. This technology is highly developed in the business world and a plethora of useful tools is available for both individuals and workgroups. However, other aspects of coordination beyond scheduling, such as process monitoring, workload scheduling, and attention focusing are not adequately satisfied by available tools.

• Team needs for triggering mechanisms for sharing as well as aids for information assembly, information translation and correlation, and report generation are only partially met. These needs must be better satisfied before the collaborative tools may be regarded as meeting military team requirements.

• When offered a choice, Navy personnel often display a preference for voice communications. Analysis of collaborative tool features in terms of alternative media for information exchange suggests that in some situations text and graphics can provide similar performance to voice at a lower cost to the team by reducing the interruptions and diversions that compromise individual productive activity.

• The utility of the tools in improving C^2W team performance will depend on the balance between the support they provide and the resources (time, attention, memory) that the team must commit to their use.

RECOMMENDATIONS

We recommend the following:

Collaborative support for military teams should be integrated into a systematic conceptual framework that considers task requirements, military team structure and procedures, and the costs/benefits of proposed solutions

The conceptual framework for supporting team activities offered in this report should be used as a basis for evaluation of collaborative technologies in military settings.

Further development work should:

- Define the range of military team tasks and support requirements;
- Refine and apply the COLAB measurement methodology(Feher, et. al, 1996) to evaluate the benefits and costs of particular support tool features for a range of military team tasks;
- Assemble a set of potentially useful collaborative features into tools that are custom-tailored to support C^2W tasks.
- Once such C^2W-targeted support systems are designed, they should be evaluated by how well they support specific C^2W collaborative requirements, and by whether their demands on the time, attention, and memory resources of the team are appropriately balanced with demands of other C^2W tasks.

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Several of the tools evaluated in this report provided useful features for transferring information between team members. The ability to exchange documents from geographically distributed locations, and the option to use various asynchronous modes of communication that do not require the simultaneous attention of all participants were particularly attractive.

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